every day should be in close co-operation with his colleagues in design and research work, who are generally of more theoretical turn of mind, but who do not have the opportunity of prolonged observation of the practical application in the field and often do not appreciate sufficiently the problems involved. There can be no questioning of the fact that knowledge already at hand, properly co-ordinated, analyzed, and understood, is the most powerful tool available for further development.

LOW COST BITUMINOUS ROADS

By Chas. L. Wilson, Oklahoma State Highway Engineer, Oklahoma City, Oklahoma.

The ever-increasing demand of the traveling public for roads usable in all weathers—smooth, dustless, and safe—has added greatly to the responsibilities and problems of all agencies of government charged with the construction and maintenance of roads.

It was apparent some years ago that the revenues available would not permit extensive construction of so-called high-type surfacing (even in states where large bond issues were voted) with any hope of completing the job. This was essentially true of states that were proceeding on the "pay-as-you-go" plan. In an effort to solve this complex problem the different states turned to cheaper materials of all kinds with results which in many cases were neither pleasing to the traveling public nor gratifying to the state highway departments.

It is my opinion that all of our known surfacing materials have a place in our future road planning throughout the nation, as the spot can be found where some particular material, considered from all angles, will best serve the requirements of traffic service and economy. The object of this paper will be to show that low cost bituminous materials, or, more specifically, liquid asphalts, are no exception; that roads surfaced with such materials at low cost have a definite place in our future road planning and that certain results may be obtained from their use.

The term "low cost" is within itself indefinite, as at best it can be considered only as a relative term, for what is considered low cost by some may by others be considered not only high cost but prohibitive cost—according to funds available and the mileage to be improved or needing improvement.

While in Oklahoma we have constructed asphalt surfaces on heavy gravel and stone bases at costs ranging from $10,000 to $14,000 per mile (which we considered relatively low cost roads), I shall confine my discussion to our experience with surfaces and surface treatments which were constructed at an initial cost of $200 to $3,000 per mile.

Before proceeding I believe it will be well to state briefly a few facts concerning the Oklahoma Highway Department. While the Constitution provided for state roads and a commissioner of highways, the first active work of construction and maintenance under an organized department started with the establishment of a Highway Commission of three members in 1924. Because of lack of funds it was not until 1927 that an effort was made to make all state roads all-weather roads by the use of a two-inch gravel treatment, designated as maintenance gravel. In 1930, in an effort to provide dustless surfaces, an oil program was inaugurated, which included both a blotter type treatment and mat construction. This was continued through the spring and summer of 1931. The features surrounding this program resulted in an action by the Highway Commission in the fall of 1931 providing for an experimental road, and the present use of liquid asphalts started with this experiment.

This experimental section was on U. S. Highway 66 between a point west of the city of El Reno and the town of Geary and was 14.54 miles in length. This was divided into eleven sections for the purpose of allowing the use of oils of eleven different producers. No effort was made to receive bids as to price nor were there any specification requirements. Each company merely furnished the amount of oil necessary for its particular section at its own price and under its own specifications.

The road mentioned was a standard graded and drained roadway that had been graveled previously with a light maintenance coat. Aggregate for the mat was distributed in windrows over the entire distance in the amount of approximately 550 cubic yards for the 1.3 miles set apart for the separate sections. Each section was numbered and a post bearing such number was placed at each end of the section. The manufacturers or producers were invited to have representatives present during the actual construction of the mats to offer any suggestions that they might have in the use of their material.

The usual sieve analysis of the windrowed material was taken at 200-foot intervals. A prime coat was then placed over the thirty-foot roadway in three sections of ten feet each, and because of heavy traffic was blotted in immediately following the distributor in order to keep traffic from traveling in the fresh oil. This was applied at the rate of .35 gallon per square yard. The windrow was then smoothed out and mat oil applied at the rate of .3 gallon per square yard per application until stain and color tests indicated that sufficient oil had been applied, which method seemed to be very satisfactory, as the finished product showed about five per cent of oil by weight of aggregate.

The usual manipulation of mixing the mat by use of motor patrol and moving the windrow from side to side was used in this construction. After the windrows were thoroughly mixed the mat was spread over the twenty-foot roadway and allowed to compact under traffic.

This experimental section of 14.54 miles was completed at a total cost, including aggregate, of $23,777.59, or a cost of $1,634.94 per mile, including the aggregate.

The results obtained were about as varied as the number of sections. In some cases pot holes appeared very soon after completion. In other cases the surface became slick and showed considerable excess of oil. This road was completed in November, 1931, and the first extensive maintenance was started in April, 1932. Since construction a complete record has been kept of all maintenance costs on this road by sections.

Early in 1932 two sections of this road were included in a concrete paving job; therefore, the maintenance cost represents only nine of the original sections. The first year the maintenance cost on the nine sections was $8,749.26, varying from $306.75 on section 3 to $1,863.15 on section 6. The cost the second year was $3,315.55, and the third year, up to December 1, 1934, the cost was $3,068.85.

While at first it would appear that the maintenance cost the first year was far in excess of the two succeeding years, it is interesting to note that when the road was completed the traffic count was around 2,000 vehicles per day. After the first year a cut-off road was completed, which took traffic off of this road, so that at the present time traffic is estimated at 900 vehicles per day. It would be reasonable to suppose, therefore, that the difference in maintenance costs is due somewhat to the decrease in traffic.

While, in our opinion, this road was not constructed according to the best methods nor with the best of materials, we believe that it has been a good investment for the State of Oklahoma so far as economy of maintenance is concerned, as we have required more money to maintain a gravel surface on an adjacent stretch during this period. The only objection we could register was that the surface in many cases was slick and during wet weather presented a considerable hazard in the way of skidding. This, however, has been rectified to a marked degree in the last year by the placing of a seal coat composed of better asphaltic materials on the slick portions, the cost of which was included in the figures given.

A great mileage of roads in our primary system has, through necessity, been maintained in the past with a gravel surface only, and since Oklahoma is not blessed with a wide distribution of suitable gravel these surfaces have been thin and have required replacing at regular intervals. During the past three years it has been our policy to do a great deal of dust palliative surface treatment, using a high-grade liquid

asphalt. This treatment is of the blotter type and a high grade of liquid asphalt is used, which sets up a thin mat and provides a dustless surface (Fig. 1). We have completed several sections of this work, ranging in cost from $200 to $400 per mile. While this expenditure might be termed a luxury expenditure, as the prime purpose is to provide comfort, it also provides safety to the traveling public by eliminating all dust hazard.

Fig. 1. S. H. 33 in Mayes County. Showing a blotter type surface treatment on a gravel road, using a high grade liquid asphalt, averaging $300.00 per mile.

On treatments of this kind we expect only one season of wear, and each succeeding year the operation must be repeated. While this appears a rather high cost for comfort only we have found that there is an actual saving as this permits better maintenance at lower costs, as replacements of gravel are made necessary at longer periods.

In some parts of the state we were faced with the problem of roads that had been constructed through blow-sand stretches. In some cases many miles of graded section were impassable to traffic during dry weather. In order to provide a surface for this class of roadway it was the practice in the past to apply a plating of clay which, upon completion, presented a surface which was extremely slick or muddy in wet weather, and since the sand was much too fine to make a satisfactory sand-clay surface an application of gravel had to be made to make the road an all-weather road. Some three years ago it was the opinion of the department that liquid asphalts could be produced with which this sand could be mixed without the addition of any other aggregate, which would produce a stabilized surface and by which we could obtain a stabilized grade and a dustless surface.

The old method of plating with clay and gravel, because of the inaccessibility of gravel, made the cost very high, in some cases being $6,000 per mile. Numerous experiments were made in the use of different liquid asphalts, ranging in quality from a crude direct from the well, emulsified crudes, and asphaltic emulsions to liquid asphalts. These experiments were made on small stretches—sometimes not exceeding one hundred feet in length—in widely separated territories. By these experiments we determined that it was possible to use the roadside materials or more specifically the materials on the grade itself, and our first real project was constructed south of Sayre on U. S. Highway 283 in 1932.

For the first applications of liquid asphalt the distributor was dragged through with a 60-caterpillar tractor; then the surface was harrowed and disked until sufficient asphalt had been placed to stabilize the grade to a point where it would support the distributor. Then additional oil was shot and the surface mixed by motor patrols moving the material from side to side until the material was thoroughly mixed. This was found to require some two to three and one-half gallons of liquid asphalt per square yard, depending upon the particular material of which the grade had been built. This construction was completed at a cost of (in round numbers) $1,500 per mile. With additional treatments, which have not exceeded $150 per mile per year, this grade has been kept in a stable and dustless condition.

A more striking experiment of this class of work is that in Grant County on U. S. Highway 60 on a stretch of 4.4 miles extending east from the town of Pond Creek. This is a stretch of road which was constructed during a dry period when there was not sufficient moisture binding the material to support even the lightest motor traffic and it was passable to horse-drawn vehicles only with difficulty. The soil conditions were variable throughout the section and were a mixture of sandy loam and blow-sand.

The procedure on this stretch was similar to that used south of Sayre. A 65-h.p. tractor was used to pull the distributor through and the surface was shot in two ten-foot strips, followed by disks and tooth harrowers, in an endeavor to stabilize the grade. After the grade became more or less stabilized the disks and harrowers were followed by a 15- or 20-h.p. tractor pulling eight-foot blades further to mix the material. In stabilizing the grade, asphalt was applied in such quantities as could be properly mixed in the material. After the grade had been stabilized to such an extent that it would support the distributor and motor patrols, approximately 500 cubic yards per mile of the material was moved to one side and allowed to cure. A base course was then obtained by repeating the operation previously described. After the base course was stabilized the top material was spread to a ten-

foot width and liquid asphalt applied to bring the bitumen content to approximately 5.5 per cent by weight, the mixing process being the same as for mat construction. This was then smoothed out and spread over the 22-foot width in three operations or three layers in order to allow traffic to compact it. After the last distribution of surface material the entire section was shaped with a twelve-foot grader to insure a smooth surface and uniform crown.

Attention is called to the fact that with the exception of the liquid asphalt no materials were used except those which were present in the grade itself.

This construction was accomplished at a total cost of $10,885.80, or $2,474.04 per mile. Liquid asphalt was used on this job at the average rate of 2.6 gallons per square yard. The cost includes cost of labor, materials, and rental charge on equipment as well as the cost of reshaping and replacing the original grade. The resulting surface is smooth and dustless, and while it is yet comparatively new and maintenance costs of any value are not available we believe this road will render satisfactory service at reasonably economical maintenance costs. (Fig. 2).

Fig. 2. U. S. 60 in Grant County. An oiled, sand surface. Note bough protection on back slopes.

In certain parts of the highway system there are sections which carry considerable traffic, which makes it imperative that they be dustless for safety, and because of the importance of the road that it be kept in good maintenance condition. This is true of State Highway 19 from southeast of Ada to Atoka and State Highway 48 running south from Ada in Pontotoc County to and through a newly discovered oil field.

These roads had been previously graded and drained and treated with maintenance gravel surfacing of approximately

two inches in thickness. Because of the amount and kind of traffic the wear on this surface was very rapid, and it was apparent that frequent applications of gravel would be necessary to maintain these highways properly. With the added need that they be dustless, it was decided to surface these roads with liquid asphalt mats to serve the needs of traffic better as well as to cut down maintenance costs in these sections.

The grade on State Highway 48 was constructed of a heavy, black gumbo soil, and within itself provided a fair base. Gravel was hauled and distributed along this section a distance of 9.2 miles at the rate of 400 cubic yards per mile. The usual measurements and screen analyses were obtained every 200 feet along the road to determine the approximate amount of oil needed. The surface of the roadbed was first bladed to eliminate irregularities, the blading being as light

Fig. 3. S. H. 19 south of Tupelo. Gravel surface treated with liquid asphalt. Average thickness 1½ inches.

as possible so as to disturb as little of the set-up gravel on the road as possible. After this the road was primed with what we termed No. 2 Prime Oil at the rate of .3 gallon per square yard. The windrowed material was then treated with liquid asphalt in the usual manner by spreading it to a 10-foot width and mixing to uniform color, using a total of .85 gallon per square yard. This mix was then spread to a uniform width of twenty feet and allowed to compact under traffic.

The cost record on the 9.2 miles showed a total of $1,514.82 per mile and tests showed liquid asphalt of 7.9 per cent by weight, the average thickness of the mat being 1¼ inches.

State Highway 19 was laid in two sections—12.0 and 14.6 miles respectively—with approximately the same operations,

with the exception of the fact that it was necessary to open ditches on these sections and to do considerable reshaping, which added to the cost. The 12-mile section was completed at a cost of $1,442.98 and, on test of the mat, showed 7.1 per cent liquid asphalt by weight and an average thickness of 1½ inches. On the 14.6-mile section, because of the long haul on gravel, the cost was $2,327.56 per mile with a test of 7.2 per cent of liquid asphalt by weight and an average thickness of 1¾ inches. (Fig. 3).

The traffic count on State Highway 48 in January, 1935, shows a total of 3,000 vehicles per day, of which 30 per cent were heavy oil-field trucks. On State Highway 19 the count shows 1,500 vehicles per day with 10 per cent heavy trucks.

From our experience in other sections we believe that these mats can be maintained at a cost of from $300 to $500 per mile, which is less than the amount that would be required to make replacements of gravel to maintain them in good condition as gravel roads.

Fig. 4. U. S. 64, Pawnee County. Three inch oil mat, costing under $1,000 per mile.

We have one example of a liquid asphalt mat which I believe it is well to mention because of the peculiar circumstances surrounding it. This particular stretch of approximately five miles on U. S. Highway 64 east of Cleveland is a road which carries approximately 2,000 vehicles per day. The road was first constructed in 1923 as a nine-inch compacted gravel road, the gravel used being washed river gravel and binder being introduced in the form of clay and the whole compacted as stated above. This road was extremely unsatisfactory and for a period of years, from time to time as the binder was shipped out, additional binder had to be added at a considerable cost. This road is on a very bad alignment and a new road must be built before any permanent surfacing can be constructed. Because of lack of funds it was doubtful

that this could be accomplished within the next three or four years and it was decided to construct on this road a liquid asphalt mat, using as aggregate the loose material which was present on the road.

The usual methods were employed in priming the base and mixing the windrowed material with liquid asphalt. The completed job is a mat three inches in thickness, which was constructed at a total cost under $1,000 per mile. (Fig. 4). With a maintenance cost of $100 or $200 per year this mat should render good service for four or five years, or until such time as the road is relocated and permanent paving constructed. This is a special case where all aggregates were present and the only expense entering into the cost of the mat was the amount paid for liquid asphalt and the manipulation of placing it.

Fig. 5. U. S. 64, Sequoyah County. Gravel retread at $3,000 per mile carrying 800 vehicles per day.

In western Oklahoma on State Highway 14 there was a stretch of road which had been constructed of six-inch compacted gravel through Washita County. It was the desire of the county that this stretch be paved, but if this were done it appeared that the money spent on the compacted gravel would, in a measure, be wasted; so it was decided to build a two-inch retread type of surface on this road. This was accomplished with the usual methods employed in the construction of retread surfacing which, I believe, are generally known and accepted. This road was constructed at a total cost for labor and materials of $2,700 per mile.

Similarly a road in Tillman County, which is a continuation of the above road, between Frederick and the county line north, was a graded highway that had received a maintenance coat of gravel a scant two inches in thickness. It was decided to make this a dustless surface and the same type of construction was used as that employed in Washita County.

Because of the cost of materials the cost of this improvement was around $3,000 per mile. Service of these roads has been very similar, with the maintenance costs being from $300 to $500 per mile per year. This we do not consider excessive maintenance cost, as replacement of gravel on these sections to maintain them as graveled roads would exceed this amount each year. These roads carry a traffic of approximately 800 vehicles per day. (Fig. 5).

The above examples have been given in a general way without details, as it was considered that all were more or less familiar with the details of such construction. Judging from our experience gained through the use of liquid asphalts as given in the above examples, as well as many other projects we have scattered throughout the state, we firmly believe that low cost construction using liquid asphalt has a definite place in our future road planning.

In general our experience has taught us that we must in no case confuse the term "low cost" with "low quality," and that our success depends a great deal on insisting that materials furnished us are of good quality. Since the State of Oklahoma is an oil-producing state we perhaps are faced with this feature to a greater degree than other states, as it is a well-known fact that not all oil produced within the state is suitable for the manufacture of liquid asphalts for road materials. It has been, I think, generally accepted throughout the country that quality tests on liquid asphalts are both desirable and necessary. The producers in our state are beginning to realize that the manufacture of liquid asphalts for road materials is not a side line and are endeavoring to adjust their manufacturing methods to produce the best quality possible, as it is to their interest as well as ours that all jobs constructed of this type of material be durable and safe.

In using this type of construction it is hardly necessary to point out that the general condition of the grade and drainage is a material factor, as I believe that this is generally recognized. Another important feature to remember in low cost construction is the fact that it requires maintenance at the proper time and that in no case should any division of government construct more mileage of this type of road than it can reasonably expect to maintain in good condition with the funds it will have available. This is extremely important, as the people once given a dustless surface will not permit the road to be turned back into the old dusty, gravel surface without voicing protests both long and loud.

It is my opinion that the road problems of the counties of our state are, in the main, similar to the problems faced by the state highway department. If there is any difference the graver problem lies with the counties, as their revenues per mile are much less than those allotted to the state highway department. Some roads that are not on the state

highway system carry a great amount of traffic and the people demand as much on these roads as they do on those of the state system. Such roads are under county supervision and I believe that the low cost asphalt road can be utilized by the counties and that its use will be found both advantageous and economical.

We do believe that liquid asphalt roads will provide desirable and economical surfacing on secondary roads with light traffic and provide all the surfacing needed for such roads. On higher traffic roads this type of construction might be considered as super-maintenance, and can be justified where the first cost plus maintenance cost of liquid asphalt surfacing over a period of years does not exceed the cost of the proper maintenance of the road as a gravel surface for the same number of years plus an arbitrary factor of the cost justified by the additional comfort and safety of the dustless surface.

A REVIEW OF OUR STREET PAVING AND RESURFACING PROGRAM

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On June 13, 1933, the 73rd Congress passed the National Industrial Recovery Act. This law was enacted for the purpose of "encouraging national industrial recovery, to foster fair competition, and to provide for the construction of certain useful public works."

Title 11 of this law pertained to public works and construction projects, while Section 204 under Title 11 provided for emergency construction of public highways and related projects. The President was empowered to make grants to the highway departments of the various states to an amount of *not less than* $400,000,000, to be expended in accordance with the provisions of the National Highway Act, approved November, 1921, with certain exceptions as provided for in Title 11, which were as follows:

(1) For expenditures in emergency construction on the Federal Highway System and extensions thereof into and through municipalities.

(2) For expenditures in emergency construction of feeder roads to be agreed upon between the state highway departments and the Secretary of Agriculture.

Section 204 further provided for the establishing of minimum wages by each state highway department and of the method of apportioning the amounts designated by the President, and provided for the maximum hours of labor engaged on projects performed under the National Industrial Recovery Act.